

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a separator for a fuel cell and to a manufacturing method of the separator.

2. DESCRIPTION OF THE RELATED ART

A fuel cell (e.g., a solid polymer type) is produced by stacking unit cells. The unit cells are assembled by installing an anode and a cathode while sandwiching a solid polymer film between them. The unit cells are sandwiched between separators. By stacking the unit cells in a number of several hundreds, a fuel cell is produced. A fuel gas such as hydrogen, or the like, is supplied through a gas supply groove formed in one separator in the anode side and an oxidizing gas such as oxygen, or the like, is supplied to the cathode side to cause an electrochemical reaction to convert the chemical energy of the fuel into electrical energy as output.

Since electrical current generated in each unit cell flows through the separators and respective neighboring unit cells are assembled to compose a structure in series connection (in terms of a circuit) by closely attaching the separators of the respective unit cells to one another, the separators are required to have a contact resistance as low as possible between surfaces of the neighboring separators and between the contact surfaces of the separators and the electrodes closely attached to the separators. The separators are further required to have an intrinsic resistance (hereinafter referred to as "volume resistance") as low as possible.

Further, since the fuel gas and the oxidizing gas are supplied to the respective electrodes while being completely separated from each other, a high degree of gas impermeability is required. As described above, since a large number of unit cells are stuck together for assembly, the thickness of the separators is made as thin as possible. Even if the separators are made thin as described, the separators are required to have sufficiently high mechanical strength and

excellent molding precision as well from a viewpoint that fuel cells are assembled by stacking several hundreds of separators, then fastening and affixing them together.

Some well-known separators that have such characteristic properties can be made of, for example, metal sheets such as pure copper, stainless steel, and the like. In the case of such a metallic material, however, there may be a problem with material deterioration caused by hydrogen embrittlement from contact with hydrogen gas used as the fuel gas. Such metal materials may be insufficient for long-term stability.

Therefore, fuel cells that have recently been developed are employing a molded body produced by mixing a graphite powder with a thermosetting resin (e.g., phenol resin) as a binder and pressure-molding the resulting mixture into separators. Since the graphite has a low electrical resistance and excellent corrosion resistance, the problems associated with using a metal separator are improved upon. Further, since the void gaps formed in the inside of the compacted powder molded body are filled with the binder, high gas impermeability, to a certain extent, can be obtained.

Such a separator made of graphite has conventionally been produced by using a resin-mixed graphite powder. The resin-mixed graphite powder is produced by steps of stirring thermosetting resin (such as a powder phenol resin) with a volatile organic solvent (such as an alcohol) to obtain a slurry, mixing and kneading a graphite powder with the slurry, drying the resulting mixture, and then pulverizing the dried mixture to a prescribed average particle diameter. In the pulverization step, the graphite powder, whose surface is coated with the non-conductive resin by the kneading, is pulverized, and thus, a raw material powder of graphite whose surface is exposed is produced. The raw material powder is filled into a prescribed molding die and pressure-molded to form a separator for a fuel cell.

In this case, the resin content is higher, and the mechanical strength and the gas impermeability are improved. A separator made of graphite has been conventionally produced by specifying, at first, the resin amount sufficient to satisfy factors such as mechanical strength and gas impermeability necessary for a separator of a fuel cell.

However, a conventional separator made of graphite produced by the above described production method does not necessarily satisfy the electrical properties required, such as volume resistance and the like. In other words, although the electrical properties become better as the resin amount is reduced, the resin amount cannot be decreased significantly since the mechanical strength and the gas impermeability are decreased as the resin amount is decreased. Thus, a conventional separator made of graphite may not provide excellent electrical properties.

SUMMARY OF THE INVENTION

A separator for a fuel cell may be made of graphite and have mechanical strength and gas impermeability as well as excellent electrical properties is described. A method for producing such a separator is also described.

The separator for a fuel cell is made of a molded body. The molded body is produced by filling a molding die with a graphite powder coated with resin on the surface and molding the powder by applying pressure into a prescribed separate shape.

A conventional separator made of graphite may be produced by kneading resin and a graphite powder into a raw material powder containing graphite. The raw material powder surface is exposed by a pulverization step before the pressure-molding. The conductivity after the molding may be taken into consideration for producing the raw material powder. The separator is then produced by pressure-molding the raw material powder. In the process, the resin partially attaches to the surface of the graphite. If pressure-molding is carried out by a molding die filled with such a raw material powder, an isostatic fluidity of respective particles through the resin cannot be obtained. That is, a graphite powder cannot sufficiently be coated with resin. Thus, relatively large void gaps are left among the particles in a produced molded body. As a result, if the content of the resin is decreased, the strength and the gas impermeability are decreased.

On the other hand, a separator may be produced by filling a molding die with a graphite powder whose surface has previously been sufficiently coated with resin. Then, by pressure-

molding the powder, the fluidity of the respective graphite particles is improved in the molding die to produce a molded body with a small porosity. Further, the neighboring graphite particles are closely stuck to one another while voids are eliminated among the graphite particles at the time of the pressure-molding. Consequently, the conductivity among graphite particles is improved after the pressure-molding.

Pressure molding of a graphite powder sufficiently coated with resin on the surface may have a particle diameter of 15 to 125 μm at a molding pressure of 100 to 1,000 kg/cm^2 and a molding temperature of 120 to 240°C. This process gives a molded body having 40 MPa of bending strength or higher and excellent mechanical strength. Gas permeability is 10×10^{-8} $\text{cc}\cdot\text{cm}/\text{cm}^2\cdot\text{sec}\cdot\text{atm}$ or lower with a volume resistance of 10×10^{-3} $\Omega\cdot\text{cm}$ or lower and excellent electrical properties even if the resin content is as low as 10 to 24 wt. %. The obtained molded body can suitably be used as a separator for a fuel cell.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 depicts a schematic cross-sectional view showing the filling and pressurizing state of a resin-coated graphite powder in a molding die in the production process of a separator for a fuel cell;

Fig. 2 depicts a schematic cross-sectional view showing the constitution of a fuel cell-based battery; and

Fig. 3 depicts a front view of a separator incorporated in a unit cell.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of a solid polymer type fuel cell assembled using a separator of the present invention is described using a schematic figure of a general separator. As shown in Fig. 2, the fuel cell-based battery is assembled in a stack structure by stacking unit cells 5. Unit cells 5 may be stacked in a number of several hundreds. Each unit cell may be composed of a solid polymer film 1, which is an ion exchange membrane made of fluoro resin. An anode 2 and a cathode 3 may sandwich the solid polymer film 1 from both sides. Separators 4 may further sandwich them from both sides and dispose current collector plates, which are omitted in the

figure, in both sides of the united cells. Each anode 2 and each cathode 3 are made of carbon cloth woven from carbon fiber yarn, carbon paper, or carbon felt.

As shown in Fig. 3, each separator 4 has fuel gas holes 6·7 and oxidizing gas holes 8·9 in the peripheral part to pass a hydrogen-containing fuel gas through and to pass an oxygen-containing oxidizing gas through, respectively. When the unit cells 5 are stacked, the respective holes 6 to 9 penetrate the inside of each fuel cell in the longitudinal direction to form a fuel gas supply manifold, a fuel gas discharge manifold, an oxidizing gas supply manifold, and an oxidizing gas discharge manifold.

In the inner side surface of the above described holes 6 to 9, a flow channel of a groove part 12 with an optional pattern is formed. The pattern of the groove part 12 may be formed to be, for example, a lattice like shape among a large number of projected parts, which may include shapes other than the shape illustrated in the figure. Through the groove part 12, as shown in Fig. 2, a fuel gas flow channel 13 is formed between the surface of an anode 2 and a separator 4 within the separator 4 in the anode 2 side. A cooling water flow channel 14 is formed between the separator 4 and another neighboring separator 4. On the other hand, in a separator 4 in a cathode 3 side, an oxidizing gas flow channel 15 is formed between the separator 4 and the surface of the cathode 3.

In a fuel cell-based battery with the above described structure, a hydrogen-containing fuel gas is supplied from a fuel gas supply apparatus installed on the outside to the fuel gas flow channel 13 of each unit cell 5 through the fuel gas supply manifold. In the anode 2 side of each unit cell 5, the electrochemical reaction, $\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$, is caused. The fuel gas, after the reaction, is discharged outside through the flue gas flow channel 13 of each unit cell 5 and the fuel gas discharge manifold.

At the same time, an oxygen-containing oxidizing gas (air) is supplied from an oxidizing gas supply apparatus installed on the outside to the oxidizing gas flow channel 15 of each unit cell 5 through the oxidizing gas supply manifold. In the anode 3 side of each unit cell 5, the electrochemical reaction, $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$, is caused. The oxidizing gas, after the

reaction, is discharged outside through the oxidizing gas flow channel 15 of each unit cell 5 and the oxidizing gas discharge manifold.

Following the above described electrochemical reactions, the electrochemical reaction, $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$, proceeds. By this reaction, the chemical energy in the fuel is converted to electrical energy and a prescribed battery function is performed. Incidentally, the fuel cell-based battery is operated in a desired temperature range of about 80 to 100°C. During operation, cooling water is supplied from a cooling water supply apparatus installed on the outside and circulated through the cooling water channel 14 to keep the operating temperature within the desired temperature range.

Each separator 4 is generally formed to be a thin sheet-like shape with a thickness of about 1 to 3 mm. A groove part 12 with a depth of 0.3 to 1.5 mm is formed in both sides of a separator 4, in the anode 2 side and in the cathode 3 side, so as to form the fuel gas flow channel 13, the cooling water flow channel 14, and the oxidizing gas flow channel 15.

In an embodiment, a separator employed for a solid polymer type fuel cell-based battery is made of a molded body produced by pressure-molding a graphite powder coated with resin on the surface into a prescribed separate shape under molding conditions, which are described later. The molded body has excellent mechanical strength (e.g., 40 MPa of bending strength or higher), excellent material properties (e.g., 10×10^{-8} cc·cm/cm²·sec·atm of gas permeability or lower), and excellent electrical properties (e.g., 10×10^{-3} Ω·cm of volume resistance or lower). The content of resin in the molded body is about 10 to 24 wt.%, less than that of a conventional molded body. Hereinafter, the production method of such a separator made of graphite is described.

The graphite powder to be used may be any kind of graphite such as natural graphite, artificial graphite, carbon black, kish graphite, expanded graphite, and the like. The graphite powder may optionally be selected while taking conditions such as the cost into consideration. Natural graphite and artificial graphite may be preferred due to their electrical properties. The average particle diameter of the graphite powder to be used may be in a range of 15 to 125 μm.

If the average particle diameter is smaller than 15 μm , the electrical resistance cannot be decreased sufficiently and if it is larger than 125 μm , the strength is deteriorated.

A desirable phenol resin has excellent wettability with the graphite powder. For example, any kind of resol type resin and novolak type resin may be used.

A method for producing such a graphite powder coated with resin is not substantially limited. A resin solution may be diluted with an organic solvent that has a low viscosity (e.g., methanol). The diluted resin solution may be, for example, a phenol resin solution. The resin solution may be mixed with a graphite powder, and stirred and kneaded into a slurry. Then the slurry may be granulated and dried by a spray drier to produce a graphite powder. In such a case, the mixing ratio at the mixing and kneading time is adjusted so as to control the resin content after the formation of the molded body to be 10 to 24 wt.%, preferably 14 to 18 wt.%. If the resin content is less than 10 wt.%, excellent gas impermeability is difficult to obtain and if the content is more than 24 wt.%, the volume resistance and the contact resistance, which are described later, are increased.

In an embodiment, the resin-coated graphite powder can be produced by a method in which the polymerization reaction of the resin takes place on the surface of the graphite powder during the stirring of the resin raw material solution. For example, in the case of forming a phenol resin coating, a graphite powder is added to a reaction container loaded with phenols, formaldehydes, a reaction catalyst, and another general reaction solvent. The mixture is heated to a prescribed temperature while being mixed and stirred to produce a resin-coated graphite powder. The phenol resin adheres to the surface of the graphite powder and enters in lamellar graphite powder to firmly stick to the graphite powder.

Phenols may include phenol and phenol derivatives. Other than phenol, examples include trifunctional phenols such as m-cresol, resorcinol, and 3,5-xyleneol; tetrafunctional phenols such as bisphenol A, and dihydroxydiphenylmethane; bifunctional o- or p-substituted phenols such as o-cresol, p-cresol, p-tert-butylphenol, p-phenylphenol, p-cumylphenol, p-nonylphenol, 2,4- or 2,6-xyleneol, and the like. In some embodiments, halophenols having

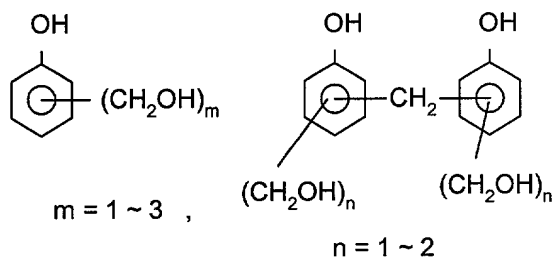
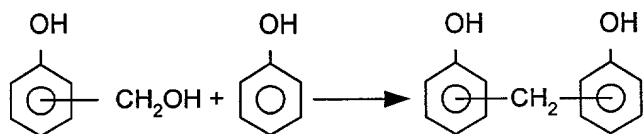
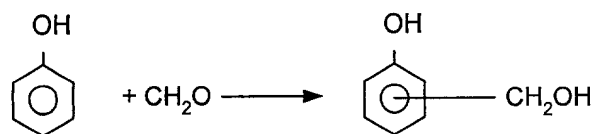
chlorine or bromine as a substituent are also usable. A plurality of these compounds may also be used in a mixture.

Formaldehydes such as formalin may be used. Those in the form of paraformaldehyde may also be used. In some embodiments, some or most of the formaldehyde may be substituted with furfural or furfuryl alcohol.

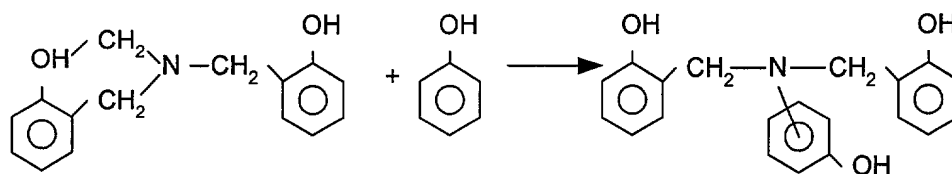
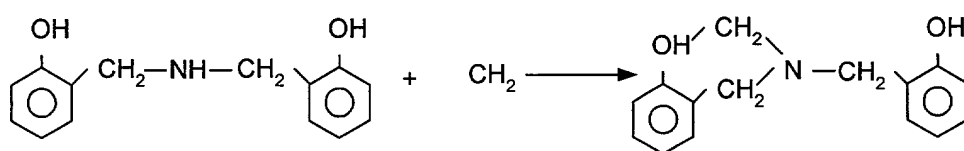
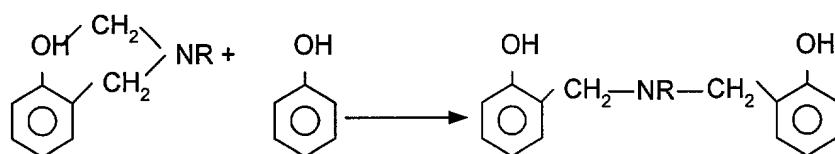
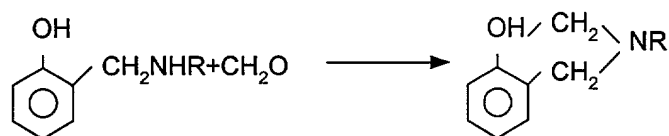
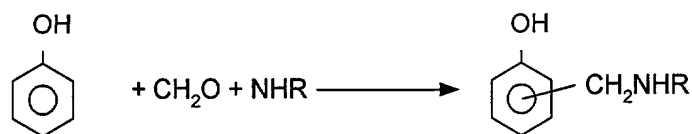
A reaction catalyst may include those capable of producing an -NCH₂, -OCH₂, or -SCH₂ bond between the benzene ring of the phenols and a benzene ring in a final structural formula of the phenol resin. For example, the reaction catalyst may include hexamethylene tetramine, ammonia, and basic substances such as primary and secondary amines (e.g., methylamine, dimethylamine, ethylenediamine, monoethanolamine and the like). In some embodiments, a basic catalyst such as hydroxides of alkali metals and alkaline earth metals and tertiary amines may be used, which are commonly used at the time of phenol resin synthesis.

The following reaction formulas shown as Chem. 1 and Chem. 2 are examples of the general reaction formulas:

Chem. 1



Chem. 2



(in the formula, the reference character R denotes hydrogen or a lower alkyl such as methyl, ethyl and the like.).

In some embodiments, the phenol resin obtained as shown for Chem. 1 and Chem. 2 may include a phenol resin having an -SCH₂ bond between the benzene rings.

These phenols, formaldehydes, and the reaction catalysts are loaded into a reaction container such as a reaction vessel. A graphite powder is added and then the reaction of the phenol and the formaldehydes is caused in the presence of the graphite powder. A resin-coated graphite powder in which phenol resin firmly adheres to the surface of the graphite powder can be obtained.

The resin-coated graphite powder obtained by the above described production method is filled in a die having a molding space corresponding to a prescribed separator shape and pressure-molded. Molding conditions may include a molding pressure of 100 to 1,000 kg/cm² and a molding temperature of 120 to 240°C. If the molding pressure is lower than 100 kg/cm², the density of the obtained molded body is low and the volume resistance may be too high to make a separator with excellent conductivity. On the other hand, if pressure higher than 1,000 kg/cm² is applied, the resin is extruded out and the graphite particles are unevenly distributed in the peripheral regions of the molded body, and thus the contact resistance is increased.

Although the molding temperature can properly be set corresponding to the heating properties of the resin, it may be preferable to set the temperature generally at 120°C or higher in order to obtain good fluidity of the graphite powder and good molding properties in the molding die in case the resin content is small. If the temperature exceeds 240°C, a swelling phenomenon in the molded body occurs. If the temperature is further increased, resin carbonization can take place.

The separator, as shown schematically in Fig. 1, can be produced using a graphite powder 21 whose surface is coated with resin 20 by filling a molding die with the graphite powder and molding the graphite powder using molding conditions described herein. In the pressure-molding process, owing to the resin softening at first by heating, the respective graphite particles may show fluidity in responding to the resin in the molding die. Thus, the obtained molded body is well-fitted with the die even after the resin is hardened, i.e., the obtained molded body is provided with a high shape precision.

The resin 20 covering the surface of the respective raw material graphite particles 21 may flow towards the voids B among the respective particles 21 along the surface of the particles 21 in the regions A among the particles 21. The particles 21 may contact one another during the molding pressure application. As a result, the surfaces of neighboring raw material graphite particles 21 are brought into contact with one another and a good electrical communication state is produced among the raw material graphite particles 21. Furthermore, a resin extruded in the

regions where particles are brought into contact with one another may gather in the gaps and be surrounded with the respective raw material graphite particles 21 to fill the gaps. As such, fluidity of the resin 20 is evenly generated around the respective raw material graphite particles 21 entirely on the inside of the molding die so that the respective raw material graphite particles 21 surrounding the gaps are also firmly bonded to one another through the resin. Thus, filling the gaps to form a molded body.

Even if the content of the resin is decreased, using raw material graphite particles whose surfaces are respectively coated with the resin makes it possible to obtain a molded body in which gaps formed among the graphite particles are almost completely filled with the resin. Such a molded body may have excellent mechanical strength and low gas permeability.

Moreover, under the above described pressure-molding conditions, since the resin is discharged towards the gaps among the raw material graphite particles 21 from neighboring regions of particles 21 to bring these particles 21 into contact with one another, an excellent electrical communication state may be obtained. Thus, it is possible to obtain a molded body that has an electrical property of excellent volume resistance. For example, a volume resistance of $10 \times 10^{-3} \Omega \cdot \text{cm}$ or lower may be attributed to the low resin content as a whole.

In the fuel cell-based battery composed by stacking unit cells 5 in a number of several hundreds, the inner resistance is considerably affected by the contact resistance between mutually closely attached separators in neighboring unit cells 5-5 in addition to the volume resistance of the separator itself. In the case of the separator made of graphite using a process as described herein, contact resistance may be low. For example, in the case of a conventional separator made of graphite, the resin content cannot be decreased to around 30 wt.% or lower because of the above described reasons. At the time when a graphite powder mixed with such a high amount of the resin is pressure-molded, the resin is extruded out to the peripheral part of the molded body from the gaps among the graphite particles to increase the resin ratio in the surface of the molded body. As a result, the separator has a high contact resistance as described above.

In an embodiment, if the resin content is decreased to 24 wt.% or lower, the desired mechanical strength and gas impermeability can be maintained. The separator obtained may be provided with a low contact resistance. Using such a separator, a fuel cell-based battery with low inner resistance and high power generation efficiency can be assembled. Further, the thickness of the separator can be made relatively thin and a fuel cell-based battery can be made small and light in weight.

Examples

Hereinafter, the present invention will be described along with examples, however the present invention is not at all restricted to these examples or to the above described embodiments. It is possible for the present invention to be modified variously within the true scope of the invention.

Example 1

A reaction container was loaded with a graphite powder (with an average particle size of 100 μm), phenol, formaldehyde, reaction catalyst (hexamethylenetetramine or ammonia together with a caustic soda solution), and a reaction solvent. While being mixed and stirred, the mixture was heated at 80°C for 1 hour. The content of the reaction container was cooled to room temperature and after the stirring was stopped, the black granular substance precipitated separately from the solvent in the reaction container was discharged out and washed with water. The resulting substance was separated from the solvent by filtering and dried to obtain a resin-coated graphite powder. The content of the resin in the resin-coated graphite was 14 %.

Then, the resin-coated graphite powder was filled into a molding die and pressure-molded at a molding pressure of 200 kg/cm² and a molding temperature of 160°C to produce a specimen for measuring a variety of characteristic properties, which are described later.

Example 2

A resin-coated graphite powder was produced in the same manner as in example 1, except that a raw material graphite powder with an average particle diameter of 60 μm was used in place of the graphite powder in example 1. The content of the resin in the resin-coated graphite was 18 %. Next, using the obtained resin-coated graphite powder, a specimen was produced in the same molding manner in the same molding conditions as those of example 1.

Example 3

A resin-coated graphite powder was produced in the same manner as in example 1, except that a raw material graphite powder with an average particle diameter of 45 μm was used in place of the graphite powder in example 1. The content of the resin in the resin-coated graphite was 21 %. Next, using the obtained resin-coated graphite powder, a specimen was produced in the same molding manner in the same molding conditions as those of example 1.

Comparative example 1

A resin-coated graphite powder was produced in the same manner as in example 1, except that a raw material graphite powder with an average particle diameter of 25 μm was used in place of the graphite powder in example 1. The content of the resin in the resin-coated graphite was 25 %. Next, using the obtained resin-coated graphite powder, a specimen was produced in the same molding manner in the same molding conditions as those of example 1.

Comparative example 2

A resin-coated graphite powder was produced in the same manner as in example 1, except that a raw material graphite powder with an average particle diameter of 130 μm was used in place of the graphite powder in example 1. The content of the resin in the resin-coated graphite was 8 %. Next, using the obtained resin-coated graphite powder, a specimen was produced in the same molding manner in the same molding conditions as those of example 1.

Comparative example 3

After the powdery phenol resin was pulverized and mixed by a ball mill, methanol was added to obtain a slurry of the phenol resin. The slurry was mixed with a raw material graphite powder with an average particle diameter of 125 μm , similar to that of example 1. After being stirred at 60°C for drying, the resulting mixture was pulverized by a mixer to obtain a resin-graphite mixed powder. Additionally, magnesium stearate was added in the middle of the pulverizing and mixing step of the phenol resin.

The content of the resin in the resin-graphite mixed powder obtained in the above described manner was 18 % and using the obtained mixed powder, a specimen was produced in the same pressure-molding manner in the same molding conditions as those of example 1.

Using the respective specimens obtained in examples 1 to 3 and comparative examples 1 to 3, the compressive strength, the bending strength, the contact resistance, the intrinsic resistance, and the gas permeability were measured according to the following respective measurement methods. Results are shown in Table 1.

Measurement method:

(1) compressive strength

measured according to JIS K 7208 (specimen: 10 mm square x 4 mm height);

(2) bending strength

measured according to JIS K 7203 (specimen: 10 mm width x 4 mm height x 80 mm length);

(3) contact resistance

voltage was measured by laminating two specimens (20 mm square x 1 mm thickness) between measurement electrodes, applying and contact plane pressure of 25 kg/cm^2 , and applying electric current of 1 A and then contact resistance was calculated;

(4) intrinsic resistance

volume resistivity was measured according to JIS K 7194 (2 mm plate thickness);
and

(5) gas permeability

gas permeation amount of nitrogen gas was measured while the pressure
difference of 1 atm being generated between both sides of a specimen and the gas
permeability was calculated.

Table 1

		graphite average particle diameter	resin content	compressive strength	bending strength	contact resistance	intrinsic resistance	gas permeability
		μm	%	MPa	MPa	$\Omega \text{ cm}^2$	$\Omega \text{ cm}$	$\frac{\text{cc} \cdot \text{cm}}{\text{cm}^2 \cdot \text{s} \cdot \text{atm}}$
example	1	100	14	62	44	5×10^{-3}	3×10^{-3}	not higher than 5×10^{-6}
	2	60	18	81	49	8×10^{-3}	6×10^{-3}	not higher than 5×10^{-6}
	3	45	21	94	53	8×10^{-3}	6×10^{-3}	not higher than 5×10^{-6}
comparative example	1	25	25	113	60	15×10^{-3}	11×10^{-3}	not higher than 5×10^{-6}
	2	130	8	50	30	5×10^{-3}	3×10^{-3}	5×10^{-6}
	3	125	18	60	38	10×10^{-3}	8.7×10^{-3}	5×10^{-3}

As shown in Table 1, even if the resin-coated graphite powder is used, the contact resistance and the intrinsic resistance were high in the comparative example 1 where the resin content exceeds 24 wt.%. The compressive strength and the bending strength were low and the gas permeability was high in the comparative example 2 where the resin content was less than 10 wt.%. In comparative example 3, where a resin-graphite mixed powder produced by adding a graphite powder to the resin, stirring them, and then pulverizing the resulting mixture was used in place of the resin-coated graphite powder, the bending strength was low and the specimen was inferior in gas permeability as well as the contact resistance and the intrinsic resistance.

In examples 1 to 3 where resin-coated graphite powders had an average particle diameter of 10 to 125 μm and a resin content of 10 to 24 wt.%, the molded bodies obtained were excellent in compressive strength and bending strength and had low contact resistance and intrinsic resistance.

Additionally, further specimens (1.5 mm thickness x 250 mm length x 250 mm width) for molding precision were produced and the thickness was measured at 25 points of a lattice. The average value and the difference of the respective measured values from the average value were calculated to evaluate the molding precision. Any specimen of examples 1 to 3 was found with a thickness precision within $\pm 15 \mu\text{m}$ or lower, which shows excellent molding precision.

As described above, a separator produced by pressure-molding a graphite powder whose surface is coated with resin has excellent mechanical strength, gas impermeability, and excellent electrical characteristic properties. A fuel cell-based battery with excellent capability can be produced using such a molded body.